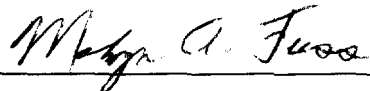


I declare, under penalty of perjury, that the foregoing is true and correct.

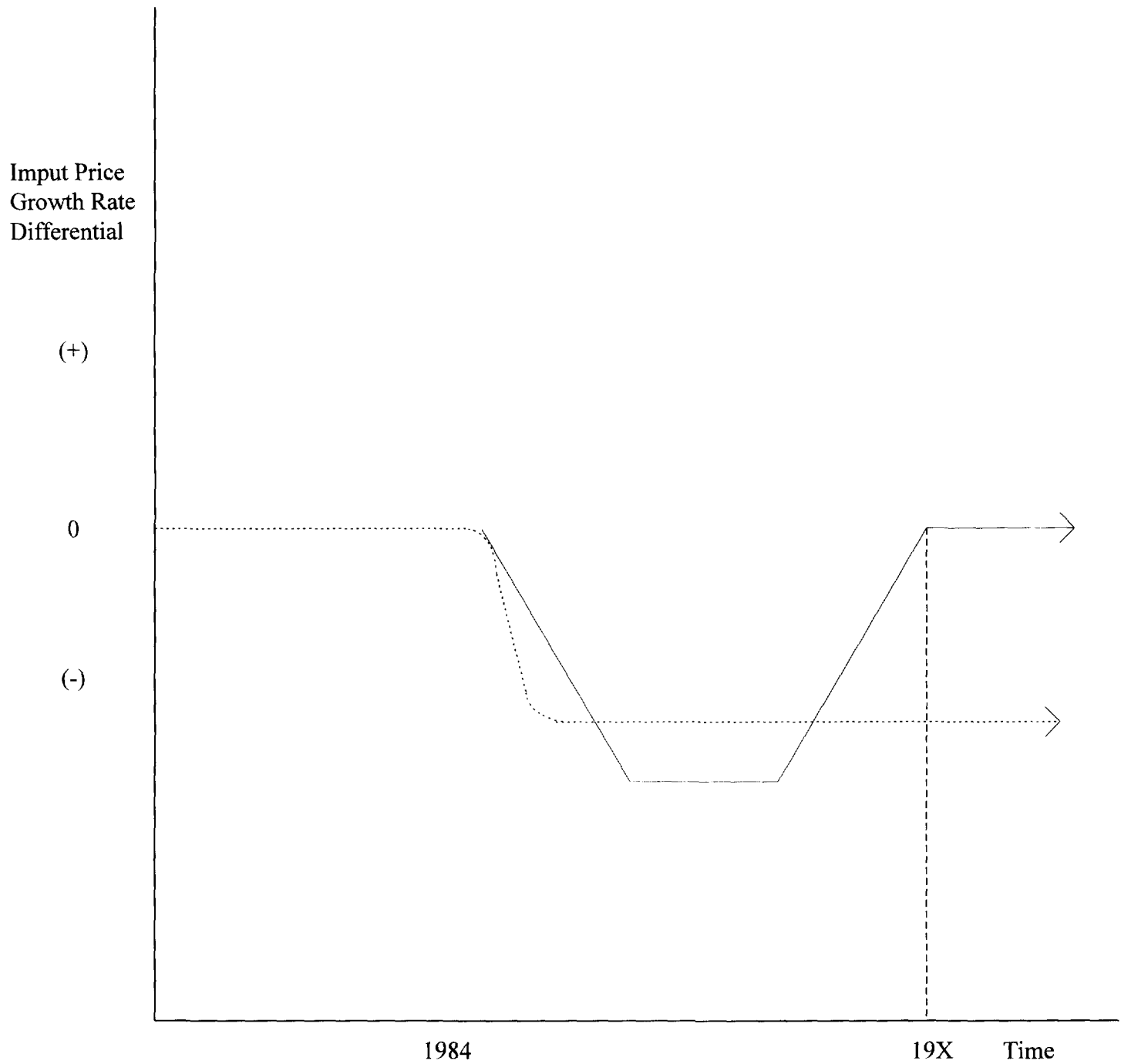
Executed on December 15, 1995

A handwritten signature in cursive script, reading "Melvyn A. Fuss", is written over a horizontal line.

Melvyn A. Fuss

Figure 1

**Competing Hypothesis Concerning the
Input Price Growth Rate Differential**



.....> The Permanent Change Hypothesis

————> The Temporary Change Hypothesis

Technical Appendix

(1) The Statistical Model in Appendix F and the Two Competing Hypotheses

In Appendix F, Bush and Uretsky estimate the following two models:

$$\text{LEC Input Price Growth} = a + b*(\text{US Input Price Growth}) + c*\text{Divestiture} + d*\text{Moody} \quad (2)$$

$$\text{LEC-US Input Price Growth} = a + c*\text{Divestiture} + d*\text{Moody} \quad (3)$$

where Moody is the yield on public utility bonds used by Christensen as the financial cost of capital, and Divestiture is a dummy variable which takes the value 1 for the years 1984-92 and 0 otherwise. The coefficients a, b, c, and d are parameters to be estimated.

If the divestiture coefficient c is negative, the data support the hypothesis of a structural shift towards lower relative LEC input price growth over the 1984-92 period, compared to an hypothesis that there was no structural change after 1984. Since the data sets used for estimation end in 1992, a value of c less than zero supports the permanent change hypothesis if the additional inference is made that the 1984-92 result can be projected into the future on a continuing basis.

Equations (2) and (3) can be adjusted to reflect the temporary change hypothesis by changing the definition of the dummy variable. Instead of the label "Divestiture" we will label the dummy variable DX, and construct it in the following way.

$$\begin{aligned} DX &= 1 \text{ for the period } 1984 \text{ to } 19X-1 \\ &= 0 \text{ otherwise} \end{aligned}$$

For example, D90 will be a dummy variable which takes on the value 1 for the period 1984-89 and 0 otherwise. In other words, if D90 is the dummy variable in equations of the form (2) and

(3), the long run relationship between LEC and US input prices will exist up to 1984; a structural change will occur during the 1984-89 period; and the long-run relationship will resume after 1989 (i.e. beginning in 1990). This is just a description of the temporary change hypothesis with $X=90$.

The temporary change hypothesis will be represented by equations (4) and (5):

$$\text{LEC Input Price Growth} = a + b \cdot (\text{US Input Price Growth}) + c \cdot DX + d \cdot \text{Moody} \quad (4)$$

$$\text{LEC-US Input Price Growth} = a + c \cdot DX + d \cdot \text{Moody} \quad (5)$$

In equations (4) and (5), X will be chosen in accordance with model selection criteria used by econometricians. The details are contained in the following section. Having chosen X , I will compare the results of equations (4) and (5) with (2) and (3). This comparison is our test of the temporary change hypothesis against the permanent change hypothesis.

(2) Model Selection for the Temporary Change Hypothesis

The criterion used to select the model to represent the temporary change hypothesis was minimization of the standard error of the regression (SER). Because the competing design matrices were all of the same dimensionality (i.e., the same number of right-hand side variables), standard error minimization results in the same decision rule as other selection criteria such as the Akaike Information Criterion (AIC), Amemiya's precision criterion (PC) and the Schwartz Criterion (SC).

Table A1 contains the values of the SER for X ranging from 85 to 92. The data sets used are the Christensen data set (1949-1992) and the NERA data set (1960-1992). The

equations estimated are equations (4) and (5) from the previous section. From this table it can be seen that the SER is minimized at $X=90$ for all four equation - data set combinations. Hence the appropriate choice of the DX variable is D90.

Table A2 is constructed in the same way as table A1 except now a 1993 data point is added to the sample. The model selection results are invariant to the added data. The preferred choice is still $DX = D90$.

Since the X which satisfies the model selection criteria is $X=90$ for both equations (4) and (5), the temporary change hypothesis can be stated in the following way: "According to the data, the process of competitive equipment price declines which competed away the excess profits of the formerly dominant incumbent equipment manufacturers occurred over the 1984-89 period. By the 1990 growth year, the growth rate of LEC input prices resumed their earlier long-term relationship with US input prices."

(3). The Comparative Regression Results

Appendix F presents results of estimating equations (2) and (3) for both the NERA (1960-92) and Christensen (1949-92) data sets. In this section, I reproduce Appendix F's regression results and provide regression results for equations (4) and (5) for the same two data sets (when $X=90$).

Christensen Data Set

The regression equations estimated in Appendix F corresponding to equations (2) and (3) were (t-statistics in parenthesis):

$$\begin{aligned} \text{LEC Input Price Growth} = & -.0027 \quad +.3402*(\text{US Input Price Growth}) \\ & (-0.20) \quad (1.46) \\ & -.0579*\text{Divestiture} \quad +.6489*\text{Moody} \\ & (-3.81) \quad (3.10) \end{aligned} \quad (2')$$

$$R^2 = .43$$

$$\text{Durbin Watson Statistic} = 1.80$$

$$\begin{aligned} \text{LEC-US Input Price Growth} = & -.0157 \quad -.0440*\text{Divestiture} \quad +.4080*\text{Moody} \\ & (-1.14) \quad (-2.83) \quad (1.78) \end{aligned} \quad (3')$$

$$R^2 = .17$$

$$\text{Durbin Watson Statistic} = 2.08$$

The corresponding regression estimates of equations (4) and (5) with X=90 are as follows (t-statistics in parenthesis):

$$\begin{aligned} \text{LEC Input Price Growth} = & -.0062 \quad +.3454*(\text{US Input Price Growth}) \\ & (-0.51) \quad (1.71) \\ & -.0830*\text{DX} \quad +.6874*\text{Moody} \\ & (-5.46) \quad (3.85) \end{aligned} \quad (4')$$

$$R^2 = .56$$

$$\text{Durbin Watson Statistic} = 1.74$$

$$\begin{aligned} \text{LEC-US Input Price Growth} = & -.0194 \quad -.0703*\text{DX} \quad +.4080*\text{Moody} \\ & (-1.55) \quad (-4.32) \quad (2.35) \end{aligned} \quad (5')$$

$$R^2 = .32$$

$$\text{Durbin Watson Statistic} = 2.10$$

NERA Data Set

The regression equations estimated in Appendix F corresponding to equations (2) and (3)

were (t-statistics in parenthesis):

$$\begin{aligned} \text{LEC Input Price Growth} = & -.0046 \quad +.3140*(\text{US Input Price Growth}) \\ & (-0.23) \quad (0.99) \\ & -.0480*\text{Divestiture} \quad +.5794*\text{Moody} \quad (2'') \\ & (-3.34) \quad (2.47) \end{aligned}$$

$$R^2 = .44$$

$$\text{Durbin Watson Statistic} = 2.12$$

$$\begin{aligned} \text{LEC-US Input Price Growth} = & -.0251 \quad -.0338*\text{Divestiture} \quad +.3419*\text{Moody} \quad (3'') \\ & (-1.38) \quad (-2.49) \quad (1.55) \end{aligned}$$

$$R^2 = .18$$

$$\text{Durbin Watson Statistic} = 2.01$$

The corresponding regression estimates of equations (4) and (5) with X=90 are as follows (t-statistics in parenthesis):

$$\begin{aligned} \text{LEC Input Price Growth} = & -.0114 \quad +.2874*(\text{US Input Price Growth}) \\ & (-0.75) \quad (1.20) \\ & -.0747*\text{DX} \quad +.6857*\text{Moody} \quad (4'') \\ & (-5.97) \quad (3.78) \end{aligned}$$

$$R^2 = .66$$

$$\text{Durbin Watson Statistic} = 2.21$$

$$\begin{aligned} \text{LEC-US Input Price Growth} = & -.0324 \quad -.0613*\text{DX} \quad +.4543*\text{Moody} \quad (5'') \\ & (-2.12) \quad (-4.67) \quad (2.46) \end{aligned}$$

$$R^2 = .43$$

$$\text{Durbin Watson Statistic} = 2.01$$

A comparison of equation (2) with (4), and (3) with (5) demonstrates the superiority of the temporary change hypothesis relative to the permanent change hypothesis in terms of which version fits the data better. The goodness of fit R^2 statistics are higher (.56 versus .43 and .32 versus .17 for the Christensen data set; .66 versus .44 and .43 versus .18 for the NERA data set). In addition, the important coefficients (c and d) are more significant for both data sets under the temporary change hypothesis.

While the above comparison is a heuristic, informal method of choosing between competing hypotheses, a formal procedure (described in detail in the following section) leads to the same conclusion. Using the method of non-nested hypothesis testing, (2) is rejected in favour of (4), and (3) is rejected in favour of (5). These rejections are statistically significant.

When a 1993 data point is added to the data used in Appendix F the conclusions reached in the preceding paragraph remain unchanged. (See the next section for details.)

4. Tests of the Permanent Change Hypothesis versus the Temporary Change Hypothesis

From a statistical perspective, the two hypotheses differ in the choice of the variable attached to the coefficient c in the regression equations. For this reason, the competing hypotheses are not nested in one another (i.e. one hypothesis is not a special case of the other hypothesis). The usual methods of testing hypotheses is restricted to nested hypotheses. However, econometricians have developed procedures for testing non-nested hypotheses of the type represented in the current context. A commonly used test statistic for testing non-nested hypotheses is Davidson and MacKinnon's J Test.¹ This test can be described as follows.

¹Theoretical discussions of the J Test can be found in Davidson, R. and J.G. MacKinnon, "Several Tests for Model Specification in the Presence of Alternative Hypotheses", *Econometrica*, 49, 781-793, and Davidson and

Suppose the permanent change hypothesis (H1) and the temporary change hypothesis (H2) are represented by the equations

$$\text{H1: } y = X_1 \beta_1 \quad (6)$$

$$\text{H2: } y = X_2 \beta_2 \quad (7)$$

A composite hypothesis can be written in the form

$$\text{HC: } y = (1-\alpha)(X_1 \beta_1) + \alpha(X_2 \beta_2) \quad (8)$$

where $0 \leq \alpha \leq 1$.

The actual test involves adjusting the composite hypothesis in the following two ways:

$$\text{HC1: } y = (1-\alpha)(X_1 \beta_1) + \alpha y_2 \quad (9)$$

$$\text{HC2: } y = (1-\alpha)(X_2 \beta_2) + \alpha y_1 \quad (10)$$

where y_2 is a vector of the fitted values obtained by regressing y on X_2 , and y_1 is the vector of fitted values obtained by regressing y on X_1 .

Davidson and McKinnon demonstrate that, when H1 is correct, the t statistic used to test whether $\alpha = 0$ in (9) is distributed in large samples as a standard normal variable. The test is equivalent to testing H1 against HC. Similarly, using a t statistic to test whether $\alpha = 0$ in (10) is equivalent to testing H2 against HC.

There are 4 possible outcomes of this testing procedure. Both H1 and H2 may be rejected ($\alpha \neq 0$ in both (9) and (10)); both H1 and H2 may not be rejected ($\alpha = 0$ in both (9) and (10)); H1 may be rejected but H2 is not ($\alpha \neq 0$ in (9) and $\alpha = 0$ in (10)); H2 may be rejected but H1 is not ($\alpha \neq 0$ in (10) and $\alpha = 0$ in (9)).

Tables A.3 and A.4 present the results of testing the various hypotheses for the

Christensen and NERA data sets. Table A.3 is based on the data used in Appendix F. In all cases H1 (the permanent change hypothesis) is rejected at conventional significance levels. In no case is H2 (the temporary change hypothesis) rejected. The temporary change hypothesis clearly dominates the permanent change hypothesis as an explanation of the input price growth rate differential. The same conclusion is apparent from the results of table A.4, where a 1993 data point has been added to the data sets.

An alternative non-nested hypothesis testing procedure is the Cox Test², a procedure based on the likelihood ratio. To test whether H1 (the permanent change hypothesis) is correct, form the expression

$$c_{12} = (N/2) \cdot \ln(s_2^2/s_{21}^2) \quad (11)$$

where N is the number of observations in the sample,

s_2^2 is the regression mean residual sum of squares under H2,

$$s_{21}^2 = s_1^2 + (1/N) \cdot (b_1' X_1' M_2 X_1 b_1)$$

where s_1^2 is the regression mean residual sum of squares under H1

b_1 is the maximum likelihood estimate of β_1

$$M_2 = I - X_2(X_2' X_2)^{-1} X_2'$$

The estimated variance of c_{12} is calculated as

² The Cox Test was first proposed in Cox, D.R., "Tests of Separate Families of Hypotheses", *Proceedings of the Fourth Berkeley Symposium on Mathematical Statistics and Probability*, Vol. 1, University of California Press, Berkeley, 1961 and Cox, D. R. "Further Results on Tests of Separate Families of Hypotheses", *Journal of the Royal Statistical Society, Series B*, 24, 406-424. This testing procedure was derived in a regression framework by Pesaran, M.H., "On the General Problem of Model Selection", *Review of Economic Studies*, 41, 153-171. A textbook presentation of the Cox Test can be found in Greene, W.H., *Econometric Analysis*, MacMillan, 1990, chapter 7.

$$\text{var}(c_{12}) = [s_1^2/(s_{21}^2)^2][b_1'X_1'M_2M_1M_2X_1b_1] \quad (12)$$

where $M_1 = I - X_1(X_1'X_1)^{-1}X_1'$.

If the hypothesis H1 is true, the test statistic

$$q_{12} = c_{12}/[\text{var}(c_{12})]^{1/2} \quad (13)$$

is distributed in large samples as a standard normal variable.

A test statistic to test whether H2 is correct can be obtained by interchanging the subscripts 1 and 2 in the above expressions.

As was the case with the J Test, there are four possible outcomes. H1 is correct and H2 is not; H2 is correct and H1 is not; neither H1 nor H2 is correct; both H1 and H2 are correct.

Tables A.5 and A.6 contain the results of using the Cox Test to test the competing hypotheses. In all cases H1 (the permanent change hypothesis) is rejected at conventional significance levels, whereas H2 (the temporary change hypothesis) is not. Clearly the temporary change hypothesis is the preferred explanation of the data according to the Cox Test (as well as according to the J Test).

Table A1Values of the Standard Errors of RegressionData to 1992

DX	Christensen Data Equation (4)	Christensen Data Equation (5)	NERA Data Equation (4)	NERA Data Equation (5)
D85	3.927	3.973	3.503	3.465
D86	3.816	3.901	3.383	3.374
D87	3.777	3.887	3.358	3.368
D88	3.748	3.891	3.342	3.381
D89	3.458	3.676	2.977	3.105
D90	3.064	3.400	2.428	2.730
D91	3.519	3.758	3.106	3.242
D92	3.437	3.740	3.021	3.236

Table A2Values of the Standard Errors of RegressionData to 1993

DX	Christensen Data Equation (4)	Christensen Data Equation (5)	NERA Data Equation (4)	NERA Data Equation (5)
D85	3.935	3.963	3.488	3.422
D86	3.835	3.895	3.382	3.333
D87	3.804	3.883	3.366	3.329
D88	3.782	3.888	3.360	3.343
D89	3.518	3.685	3.036	3.078
D90	3.165	3.425	2.563	2.719
D91	3.585	3.767	3.169	3.213
D92	3.520	3.751	3.114	3.209
D93	3.548	3.762	3.168	3.238

Table A.3

Testing the Two Competing Hypotheses Using the J TestData to 1992

Data Set and Equation Nos.	Hypothesis	t - Statistic for α	Critical 5% Value of t	P-Value
Christensen Eqs (2)&(4)	H1 versus HC	3.37	1.96	.0008
	H2 versus HC	0.57	1.96	.5693
Christensen Eqs (3)&(5)	H1 versus HC	2.94	1.96	.0033
	H2 versus HC	-0.09	-1.96	.9247
NERA Eqs (2)&(4)	H1 versus HC	4.14	1.96	.0000
	H2 versus HC	0.13	1.96	.8978
NERA Eqs (3)&(5)	H1 versus HC	3.63	1.96	.0003
	H2 versus HC	-0.70	-1.96	.4859

Table A.4

Testing the Two Competing Hypotheses Using the J TestData to 1993

Data Set and Equation Nos.	Hypothesis	t - Statistic for α	Critical 5% Value of t	P-Value
Christensen Eqs (2)&(4)	H1 versus HC	3.01	1.96	.0026
	H2 versus HC	1.37	1.96	.1705
Christensen Eqs (3)&(5)	H1 versus HC	2.70	1.96	.0069
	H2 versus HC	0.52	1.96	.6016
NERA Eqs (2)&(4)	H1 versus HC	3.59	1.96	.0003
	H2 versus HC	0.96	1.96	.3391
NERA Eqs (3)&(5)	H1 versus HC	3.47	1.96	.0005
	H2 versus HC	-0.20	-1.96	.5789

Table A.5Testing the Two Competing Hypotheses Using the Cox TestData to 1992

Data Set and Equation Nos.	Hypothesis	Standard Normal Statistic (N) for α	Critical 5% Value of N	P-Value
Christensen Eqs (2)&(4)	H1 is correct	-6.00	-1.96	.0000
	H2 is correct	-0.58	-1.96	.5640
Christensen Eqs (3) &(5)	H1 is correct	-5.08	-1.96	.0000
	H2 is correct	0.09	1.96	.9294
NERA Eqs (2)&(4)	H1 is correct	-9.31	-1.96	.0000
	H2 is correct	-0.11	-1.96	.9109
NERA Eqs (3)&(5)	H1 is correct	-7.42	-1.96	.0000
	H2 is correct	0.55	1.96	.5800

Table A.6

Testing the Two Competing Hypotheses Using the Cox TestData to 1993

Data Set and Equation Nos.	Hypothesis	Standard Normal (N) Statistic for α	Critical 5% Value of N	P-Value
Christensen Eqs (2)&(4)	H1 is correct	-5.17	-1.96	.0000
	H2 is correct	-1.63	-1.96	.1026
Christensen Eqs (3)&(5)	H1 is correct	-4.66	-1.96	.0000
	H2 is correct	-0.55	-1.96	.5819
NERA Eqs (2)&(4)	H1 is correct	-7.61	-1.96	.0000
	H2 is correct	-1.02	-1.96	.3097
NERA Eqs (3)&(5)	H1 is correct	-7.40	-1.96	.0000
	H2 is correct	0.17	1.96	.8616

December 1995

CURRICULUM VITAE

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PERSONAL BACKGROUND

Date of Birth: March 29, 1940
Marital Status: Married, one child
Citizenship: Canadian

EDUCATION

Ph.D. University of California (Berkeley), 1970 (Economics)
M.A. University of Toronto, 1965 (Economics)
B.Sc. University of Toronto, 1963 (Mathematics and Physics)

HONOURS AND AWARDS

Province of Ontario Fellowship, 1964-65
University of California Fellowship, 1965-66
Canada Council Predoctoral Fellowships, 1966-69
American Telephone and Telegraph Post - Doctoral Fellowship in Public Utility Economics, 1971-72
Canada Council Leave Fellowship, 1978-79
Canadian Studies Visiting Professorship, Hebrew University of Jerusalem, 1987-88

PROFESSIONAL EXPERIENCE

<u>Rank/Position</u>	<u>Department</u>	<u>Institution</u>	<u>Dates</u>
Instructor	Economics	Harvard University	1969-70
Assistant Professor	Economics	Harvard University	1970-72
Associate Professor	Economics	University of Toronto	1972-79
Professor	Economics	University of Toronto	1979-present
Associate Chairman	Economics	University of Toronto	1984-85
Chairman	Economics	University of Toronto	1985-90
Research Associate	Institute for Policy Analysis	University of Toronto	1972-present
Research Associate		National Bureau of Economic Research	1983-present
Visiting Professor	Economics	Hebrew University of Jerusalem	1973
Visiting Scholar	Economics	University of California, Berkeley	1975
Visiting Scholar	Economics	Stanford University	1975-76
Visiting Professor	Economics	Hebrew University of Jerusalem	1987-88
Visiting Scholar	Research	Bank of Israel	1987-88
Editor		Journal of Productivity Analysis	1992-present

TEACHING EXPERIENCE

- (i) Harvard University
- Undergraduate
- principles
 - economics of regulation
- Graduate
- industrial organization
 - introductory econometrics
 - advanced econometrics
 - microeconomic theory
- (ii) Hebrew University of Jerusalem
- Graduate
- seminar in production theory
 - econometrics
- (iii) University of Toronto
- Undergraduate
- advanced microeconomic theory
 - industrial organization
 - econometrics
 - economics of regulation
- Graduate
- microeconomics theory
 - econometrics

CONSULTING EXPERIENCE

consultant to:

Abt Associates
Association of Canadian Distillers
Canada-U.S. Select Panel on the State of the North American Auto Industry
Canadian Cable Television Association
Chrysler Corporation
Data Resources Inc.
Edmonton Telephones
Electric Power Research Institute
Federal Department of Communications
Federal Department of Finance
Federal Department of Energy, Mines and Resources
Gulf Canada Ltd.
Ontario Hydro
Ontario Legislature
Ontario Ministry of Energy
Ontario Ministry of Transportation and Communications
Ontario Ministry of Industry, Trade and Technology
Sierra Club of Ontario
Southern New England Telephone Company
Statistics Canada
Teleglobe Canada
United States Postal Service
United States Postal Rate Commission
United States Department of Justice
Unitel / Canadian Pacific Telecommunications

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Production Economics: A Dual Approach to Theory and Applications: Vol. 2: Applications of the Theory of Production - Contributions to Economic Analysis, volume 111, North-Holland Publishing Company, Amsterdam, 1978, 338 pages (co-editor with Daniel McFadden).

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"The Demand for Energy in Canadian Manufacturing: An Example of the Estimation of Production Structures with Many Inputs", Journal of Econometrics, 5, 1, January 1977, pp. 89-116.

"The Use of Approximation Analysis to Test for Separability and the Existence of Consistent Aggregates" (with M. Denny), American Economic Review, 67, 3, June 1977, pp. 404-418.

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- "The Derived Demand for Energy in the Presence of Supply Constraints", Chapter 4 in W.T. Ziemba, S.L. Schwartz, and E. Koenigsberg, (eds.) Energy Policy Modeling: United and Canadian Experiences; Volume I: Specialized Energy Policy Models, Martinus Nijhoff, The Hague, The Netherlands, 1980, pp. 65-85.
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- "Estimating the Effects of Diffusion of Technological Innovations in Telecommunications: The Production Structure of Bell Canada" (with M. Denny, C. Everson and L. Waverman), Canadian Journal of Economics, XIV, 1, February 1981, pp. 24-43.
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